

Geoindicators Scoping Report for Olympic National Park

Strategic Planning Goal Ib4

August 14-15, 2000¹
Port Angeles, Washington

Compiled by Vicki Ozaki

June 2002

Table of Contents

SCOPING SUMMARY.....	1
INTRODUCTION	1
<i>Purpose of meeting</i>	1
<i>Government Performance Results Act (GPRA) Goal 1b4</i>	1
<i>Geoindicator background information</i>	1
<i>Park selection</i>	2
SUMMARY OF RESULTS	2
<i>Geoindicators with importance to park ecosystems</i>	4
<i>Geoindicators with significant human influence</i>	4
<i>Geoindicators with high management significance</i>	4
<i>Significant geoindicators</i>	5
SUMMARY OF RECOMMENDATIONS	6
<i>Recommendations for baseline data</i>	6
<i>Recommendations for inventory needs</i>	7
<i>Recommendations for monitoring needs</i>	10
<i>Recommendations for research needs</i>	14
<i>Recommendations to Minimize Human Influence</i>	16
<i>Recommendations for Park Planning</i>	17
LIST OF PARTICIPANTS	19
APPENDICES	20
APPENDIX A. DESCRIPTION OF 27 GEOINDICATORS	21
APPENDIX B. HUMAN INFLUENCES	22
APPENDIX C. INTRODUCING GEOINDICATORS	23
APPENDIX D. SPECIES DON'T STAND ALONG- GEOLOGY'S ROLE AND IMPORTANCE IN THE ECOSYSTEMS	24
APPENDIX E. COMPILATION OF NOTES FROM GEOINDICATOR SCOPING DISCUSSION	25
GLACIAL AND PERIGLACIAL PROCESSES	25
<i>Glacier Fluctuations</i>	26
AEOLIAN GEOINDICATORS	27
<i>Dust Storm Magnitude, Duration and Frequency</i>	27
<i>Wind Erosion</i>	28
COASTAL GEOINDICATORS	29
<i>Relative Sea Level</i>	29
<i>Shoreline Position</i>	30
<i>Dune Formation & Reactivation</i>	31
GROUNDWATER GEOINDICATORS	32
<i>Groundwater Quality</i>	32
<i>Groundwater Chemistry in the Unsaturated Zone</i>	33
<i>Groundwater Level</i>	34
SURFACE WATER GEOINDICATORS	35
<i>Lake levels</i>	35
<i>Surface Water Quality</i>	37
<i>Streamflow</i>	37
<i>Stream Channel Morphology</i>	38
<i>Stream Sediment Storage and Load</i>	39
<i>Wetland Extent, Structure and Hydrology</i>	40
TECTONICS AND GRAVITY GEOINDICATORS	41
<i>Slope failure (landslides)</i>	41
<i>Seismicity</i>	43
<i>Surface Displacement</i>	44

SOIL GEOINDICATORS	44
<i>Soil Quality</i>	44
<i>Soil and Sediment Erosion</i>	45
OTHER GEOINDICATORS	46
<i>Sediment Sequence and Composition</i>	46
ADDITIONAL GEOLOGIC ISSUES	47
<i>Avalanches</i>	47
<i>Geothermal</i>	48
<i>Intertidal Zones</i>	48

Scoping Summary

Introduction

The National Park Service and U.S. Geological Survey held a geosindicator scoping meeting for Olympic National Park (OLYM) at Port Angeles, WA on August 14-15, 2001. Participants included staff from the Olympic National Park, U.S. Geological Survey (USGS), National Park Service's (NPS) Geologic Resources Division (GRD), and other geologists and resource experts.

Purpose of meeting

The purpose of the meeting was threefold: (1) to identify significant geological processes and features that are part of the park's ecosystem, (2) to evaluate human influences on those features, and (3) to provide recommendations for studies to support resource management decisions, geologic inventory and monitoring projects, and research to fill data gaps. The scoping meeting was designed to use the participants' expertise and institutional knowledge and build on the synergy of the participants through field observations, group discussion and exchange of ideas.

Government Performance Results Act (GPRA) Goal 1b4

This meeting satisfies the requirements of the GPRA Goal 1b4, which is a knowledge-based goal that states, "Geological processes in 53 parks [20% of 265 parks] are inventoried and human influences that affect those processes are identified." The goal was designed to improve park managers' capabilities to make informed, science-based decisions with regards to geologic resources. It is the intention of the goal to be the first step in a process that will eventually lead to the mitigation or elimination of human activities that severely impact geologic processes, harm geologic features, or cause critical imbalance in the ecosystem.

Because the GPRA goal includes only 36% of the 270 natural resource parks, information gathered at this park may also be used to represent other parks with similar resources or patterns of use, especially when findings are evaluated for service-wide implications.

Geosindicator background information

An international Working Group of the International Union of Geological Sciences developed geosindicators as an approach for identifying rapid changes in the natural environment. The National Park Service uses geosindicators during scoping meetings as a means to fulfill GPRA Goal 1b4. Geosindicators are measurable, quantifiable tools for assessing rapid changes in earth system processes. Geosindicators evaluate 27 earth system processes and phenomena (Appendix A) that may undergo significant change in magnitude, frequency, trend, or rates over periods of 100 years or less and may be affected by human actions (Appendix B). Geosindicators are used as a framework to guide

the discussion and field observations during scoping meetings (Appendix C) and are considered a proxy for geologic processes. The geoindicators scoping process for National Parks was developed to help determine the studies necessary to answer management questions about what is happening to the environment, why it is happening, and whether it is significant.

The health and stability of an ecosystem may be evaluated through the geoindicators scoping process. The geologic resources of a park--soils, caves, streams, springs, beaches, volcanoes, etc.--provide the precise set of physical conditions required to sustain the biological system. Geologic processes create topographic highs and lows; influence water and soil chemistry; determine the fertility of soils, the stability of hillslopes, and the quality and quantity surface water and groundwater. These factors, in turn, can determine where, when, and how biological processes occur, such as the timing and distribution of species reproduction, the distribution of habitats, the productivity and type of vegetation, and the response of ecosystems to human impacts (Appendix D).

Park selection

This park was selected for a geologic evaluation because of its unique geologic resources and particular human use. Olympic National Park is characterized by a diversity of geologic settings--high alpine and glacial areas, large river systems, and coastal shorelines of the Pacific Ocean.

Summary of Results

During the scoping meeting, geoindicators relevant to Olympic National Park were identified and evaluated. Of the 27 geoindicators, 22 were recognized as on-going processes in park. Three additional geologic indicators (avalanches, geothermal, and tidal zones) not identified by the original 27 geoindicators were also included. Participants rated the geoindicator with respect to the importance of the geologic process on ecological health and the influence of human activity on the geoindicator (table 1 and 2). Park staff rated the significance of the geoindicator for park management. A rating of high, medium, and low was used. A summary of the scoping session discussion is included in Appendix E. The summary notes highlight additional information regarding geoindicators that may be useful to park managers.

Table 1. Geoindicators table for Olympic National Park

Geoindicator	Importance to park ecosystem	Human influence on geology	Significance for management
PERIGLACIAL AND GLACIAL			
Frozen ground activity	H	M/H	M
Glacier fluctuations	H	H^a	H
AEOLIAN			
Dust storm magnitude, duration, and frequency	L	H	L/M
Wind erosion	L	L	L
COASTAL			
Relative Sea Level (100 years)	H	H^a	H
Shoreline Position	H	H	H
Dune Formation and Reactivation	L	L	L
GROUNDWATER			
Groundwater quality (including hyporehic zones)	H?	Unknown	L
Groundwater chemistry in the unsaturated zones	H	H^b	H
Groundwater level and springs	L	L	L
SURFACE WATER			
Lake levels	H	H?	H
Surface water quality	H	M	M/H
Streamflow	H	H	H
Stream channel morphology	H	H	H
Stream sediment storage and load	H	H	H
Wetlands extent, structure, and hydrology	H	L/M	M
TECTONICS AND LANDSLIDES			
Slope failure	H	H	H
Seismicity	L	L	H
Surface displacement	L	L	H
SOILS			
Soil quality	H	Unknown	L
Soil and sediment erosion	H	H	H
OTHER			
Sediment sequence and composition*	L	L	M
<p>^a Indicators of global climate change or activities ^b Locally High H - HIGHLY influenced by, or with important utility for M - MODERATELY influenced by, or have some utility for L - LOW or no substantial influence on, or utility for Unknown - may require study to determine applicability. H? - Human influence is perceived to be high but requires more data to evaluate issue.</p> <p>* Sediment sequences and composition is a tool with great significance for enhancing the information base of the park's ecosystem, identifying human influences on the ecosystem, and providing data for management decisions and planning.</p>			

Table 2. Other Geologic Issues at Olympic National Park

Additional Geologic Issues	Importance to park ecosystem	Human influence on geology	Significance for management
Avalanches	H	L	L/M
Geothermal springs	L	H	M
Tidal zones	H	M ^a	H
^a Locally High H – HIGHLY influenced by, or with important utility for M – MODERATELY influenced by, or have some utility for L – LOW or no substantial influence on, or utility for			

Geoindicators with importance to park ecosystems

Of the geoindicators identified as relevant to Olympic National Park, 17 were considered highly significant to the park's ecosystems. In particular, all surface water, periglacial/glacial, and soils geoindicators rated high. Most of the geoindicators associated with groundwater, coastal processes and tidal zones, landslides, and avalanches also rated highly significant to park ecosystems.

Geoindicators with significant human influence

Human activities can influence natural geologic processes through extraction of natural resources, by altering natural processes such as sediment transport, visitor use impacts, park management practices and infrastructure, and land use adjacent to parks. Human induced changes can fall into two categories. There are changes that are irreversible, such as slope failures caused by trail and road construction, and those that are reversible such as soil compaction. In order to manage ecosystems and natural resources, it is essential to have a fundamental understanding of how human activities impact or alter geologic processes.

Human influence on geologic processes was rated high for 12 geoindicators. Four of the geoindicators were associated with surface water or stream processes and were: streamflow, stream channel morphology, stream sediment storage and load, and lake level. Human actions directly affect geologic processes in the park and include: shoreline position, groundwater chemistry in the unsaturated zone, dust storms, soil and sediment erosion, landslides, and geothermal springs.

Human activities outside the park boundary potentially affect the park's natural resources. Two of these geoindicators (glacial fluctuations and relative sea-level) were rated high for human influence because global climate change or activities can locally affect park resources.

Geoindicators with high management significance

Geologic processes may have a high management significance due to safety concerns, administrative use of resources, or protection of fragile natural resources from detrimental human activities. It is important for park managers to be aware of what geologic processes are active in the park and how to adapt park management to address these processes. This knowledge can greatly assist managers in making decisions to protect human safety and natural resources.

Significance for management was rated high for more than half (13) of the geoindicators. Almost all the geoindicators that rated high for human influence also rated high for management significance. Park management is concerned with mitigating and rectifying human influences on the park's resources. Most of the geoindicators associated with surface water, coastal and tidal zones, tectonics, and landslides rated high. Seismicity (earthquakes), surface displacement (uplift and subsidence), and landslides are clearly geologic hazards and need to be monitored in order to protect park visitors and staff. Tectonic and landslide processes can also affect park roads, trails and facilities. Also of concern to park management, were glacier fluctuations, and groundwater chemistry in the unsaturated zone (groundwater pollution), and soil and sediment erosion (impacts to the park's aquatic and riparian resources).

Significant geoindicators

Particular attention is paid to those geoindicators with a high rating across all three categories; (1) significance to the park's ecosystem, (2) human influence, and (3) management significance. Nine geoindicators rated high for all three categories and included:

Glacial fluctuations

Glaciers are a key feature of the park and are a highly valued resource by the visiting public. Glaciers are very important to the park's ecosystems; they provide a source of water and buffer streams from organochlorides. Climate change over the next 100 years will significantly affect this park resource.

Relative sea-level and Shoreline position

The park manages 60 miles of coastline. Changes in relative sea level may occur slowly as a result of global climate or catastrophically from large Cascadia earthquakes capable of changing the elevation of the coastline on the order of a meter or more. Future changes in relative sea-level and shoreline position may affect coastal park facilities, developments, and roads. Changes in the coastline can significantly affect the biological communities in intertidal zones of the park. The park's estuarine and coastal ecosystems will respond to changes in relative sea level or shoreline position.

Groundwater chemistry in the unsaturated zone

Groundwater chemistry in the unsaturated zone can influence groundwater quality by introducing pollutants. Septic systems in developed zones in the park can locally alter groundwater and surface water quality.

Streamflow

Streamflow is essential to maintain aquatic and riparian ecosystems along streams in the park. Streamflow determines the amount of sediment transported annually. Winter flooding occurs virtually every year and affects the park's trails, bridges and roads. Dams on the Elwah River also significantly affect stream discharge, sediment transport, and channel morphology.

Stream channel morphology and Stream sediment storage and load

Human activities have significantly modified or affected channel morphology of park streams and include rip rap, engineered log jams, bridges, gravel mining adjacent to the park boundary, logging, and dams. Timber harvesting and road building has altered slope stability and fluvial erosion on lands adjacent to the park. Increased sediment delivery to streams and channel modifications has impacted stream channels, aquatic habitat, and affected nearby coastal ecosystems. The park is concerned about impacts to stream habitat that support federally listed salmonid fish.

Slope failure

Past and present landslides continue to modify and shape the park's landscapes and is a mechanism to deliver both sediment and large wood to streams. Slope failures on private lands are associated with roads and timber harvest and increased sediment delivery affect the parks aquatic resources. Coastal bluff failures and retreat along the coastline also affects the highway.

Soil and sediment erosion

Accelerated sediment erosion and deposition from logging and road building adjacent to parklands can impede access for salmonids to park streams. Excess sediment can also bury stream habitat and degrade water quality. The park must manage for federally listed salmonid species and is concerned about impacts to salmonid habitat.

Summary of Recommendations

The following summary of recommendations lists ideas discussed during the August 14-15, 2001 scoping meeting held in Olympic National Park. The summary includes recommendations for inventory, monitoring and research studies, as well as, recommendations for specific management issues, public education, and planning.

Recommendations for baseline data

Aerial photography inventory

Aerial photography can provide a historic overview (past 65 years) of long-term changes of geologic processes and other natural resources in OLYM. Imagery can be used to support geologic inventory, monitoring, and research studies. It also can provide invaluable information for remote areas of the park. Identify and inventory existing aerial photography for parklands. Compile a database containing date of photography, photo scale, identify whether color or black and white images, type of imagery (oblique,

stereo, satellite, infra-red, orthophotography coverage), area covered, and location of photos and air photo flight lines.

Acquire additional coastal data

Dr. Curt Peterson, Portland State University, potentially has a coastal landform/geomorphology GIS layer, air photos and elevation data that covers OLYM. Contact him about the availability of his coastal data.

Contact

Curt Peterson, Oregon State University; peteronc@pdx.edu, (503) 725-3375

Additional coastal data includes geologic mapping available at 1:100,000 scale (digital or paper) and several landslide inventories. Contact Wendy Gerstel for more information.

Wendy Gerstel, Washington Division of Geology and Earth Resources;
wendy.gerstel@wadnr.gov, (360) 902-1450

Recommendations for inventory needs

Assess impacts of human activities on patterned ground and gelifluction

Map the distribution of patterned ground and gelifluction lobes and show the associated trails (social and established) and roads. Develop baseline information and establish photo points on patterned ground on Lillian Ridge and Blue Mountain. Search for historic photos of these areas to compare with present day conditions. Determine if human impacts (such as foot traffic and trail construction/location) occur on these fragile geologic resources and identify potential resource management options for protection of patterned ground.

Inventory glaciers

Inventory park glaciers from aerial photography. Check on available military satellite imagery for use in inventory of glaciers. Consider reinventorying glaciers every ten years. See also Monitor Park Glaciers project statement below.

Contact

Jon Riedel, NOCA; jon_riedel@nps.gov, (360) 873-4590 x21

References

Spicer, R.C., 1986. Glaciers of the Olympic Mountains, Washington: present distribution and recent variations: Master's thesis, Dept. of Geol. Sciences, Univ. of Washington, Seattle, WA. 158 p.

Spicer, R.C., 1989. Recent variations of Blue Glacier, Olympic Mountains, Washington, USA: Arctic and Alpine Res., 21(1), 1-21.

Inventory snow avalanche features and develop risk maps

Inventory avalanche features in the park. On a topographic base, map both current and relic avalanche features from air photos using slope indicators and vegetation. Also use GIS topographic information and snowfall data to predict locations of avalanches in the park. Monitor avalanches and develop avalanche risk maps for developed areas (roads, trails, facilities and visitor use areas).

Evaluate landslide history

Inventory landslides (debris torrents, debris flows, debris slides, large deep-seated landslides, etc), and determine distribution, frequency, and activity level of features. Use sequential air photos to document landslide history in the park from available photos that bracket pre and post large storms, and timber harvesting. Periodically update landslide mapping following large storm events or every 5-years.

Develop slope stability maps

Identify areas prone to mass-wasting events using aerial photographs, bedrock geology maps and slope gradient maps. Develop a slope stability risk analysis for landslide prone areas along developed zones in the park. Evaluate landslide risk to existing park infrastructure (roads, trails, facilities, visitor use areas).

Evaluate coastal bluff stability

Determine the cause of coastal bluff instability near roads and visitor use sites by identifying the failure mechanisms associated with rainfall/runoff versus wave cutting events. Determine the probability of wave attack and correlate with bluff erosion. Determine if human activities cause or exacerbate coastal bluff failures.

Inventory of small alpine lakes

Conduct inventory of small alpine lakes in the park. North Cascades National Park (NOCA) is a prototype park for developing protocols, and OLYM should consult with NOCA on inventory protocols.

Contact

Jon Riedel, NOCA; jon_riedel@nps.gov, (360) 873-4590 x21

Inventory and monitor large wood deposited along coastal areas

Studies by Goner et al. (1988) have documented the important role of coarse woody debris as part of estuarine and oceanic habitat. Inventory and monitor the distribution and volume of large wood deposited along the coast over time.

Reference

Maser, C., Tarrant, R.F., Trappe, J.M., and Franklin, J.F., eds., 1988, From the forest to the sea—a story of fallen. U.S.D.A., Forest Service. Pacific Northwest Research Station. General Technical Report PNW-GTR-229, p. 83-112.

website: <http://www.fs.fed.us/pnw/pubs/gtr229.htm>

Reference: Gonor, J., Sedell, J. and Benner, P., 1988, What we know about large trees in estuaries, in the sea and on the coastal beaches: *in* Maser, C., Tarrant, R.F., Trappe, J.M., and Franklin, J.F., eds., From the forest to the sea—a story of fallen trees: U.S.D.A. Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-229, p. 83-112.

website: <http://www.fs.fed.us/pnw/pubs/229chpt4.pdf>

Inventory and monitor nearshore and intertidal coastal habitats

Determine the types, location, and quality of nearshore habitats (intertidal and shallow subtidal areas). An inventory would include both biological and physical components of the intertidal. This project is ideally suited as a geologic attribute for vital signs monitoring. Develop baseline data of geomorphic habitat characterizations for biological communities and establish long-term trend monitoring of selected sites. Biologic and physical information on nearshore habitat can be used to guide and assess future land-use planning and development in coastal areas, and determine the biological impacts from changes or destruction of habitat from a rise in RSL. Also, utilize remote sensing techniques for seafloor mapping (multi-beam imagery, side scan radar, seismic reflection). Determine sediment substrates and habitat types of the nearshore/offshore areas of the park. Use seismic reflection data offshore to determine the thickness of sediment sequence for a sediment budget.

Contact

Carl Schoch, Kachemak Bay National Estuarine Research Reserve;
cschoch@bcc.orst.edu, (907) 235-4799

Reference

Puget Sound Research Conference '98 Proceedings

website:

http://www.wa.gov/puget_sound/Publications/98_proceedings/sessions/studying_nearshore.html

Reference

Schoch, G.C. and Dethier, M.N., 1998, Mapping Shorelines in Puget Sound III: Management Applications for Inventory and Monitoring. Puget Sound Research Conference, March 12 - 13, 1998, Washington State Convention and Trade Center, Seattle, Washington.

Schoch, G.C. and Dethier, M.N., 1998, Mapping shorelines in Puget Sound III—management applications for inventory and monitoring: Puget Sound Research Conference, March 12-13, 1998, Seattle, Washington, p. 573-579.

website: http://www.wa.gov/puget_sound/Publications/98_proceedings/pdfs/5a_berry.pdf

Washington State Department of Natural Resources Nearshore Habitat Program, Research Projects (includes inventory and monitoring of nearshore habitat)

website: <http://www2.wadnr.gov/nearshore/research/>

Erosion and sedimentation impacts to Lake Ozette

Increased erosion and sediment transport from adjacent private lands has impacted sockeye spawning gravels along the shoreline of Lake Ozette. Identify and quantify sediment sources in tributaries to Lake Ozette. Quantify the sediment impacts to spawning gravel quality.

Conduct basic wetlands inventory

Request technical assistance from the NPS Water Resources Division (WRD) for a wetland inventory. Focus wetland inventory efforts on existing and potentially future developed corridors. Submit a request for using a Geoscientist-in-the-Park (GIP) to help with wetlands mapping.

Wetlands Contact

Joel Wagner, NPS WRD; joel_wagner@nps.gov, (303) 969-2955

GIP Program Contact

Judy Geniac, NPS GRD; judy_geniac@nps.gov, (303) 969-2015

Map park soils

Pursue project with the Natural Resource Conservation Service (NRCS) to map soils in OLYM, NOCA, and Mount Rainier National Park (MORA). Work with Pete Biggam and Jon Riedel to coordinate soil mapping with NRCS in the three parks.

Contact

Pete Biggam, NPS GRD; pete_biggam@nps.gov, (303) 987-6948

Jon Riedel, NOCA; jon_riedel@nps.gov, (360) 873-4590 x21

Recommendations for monitoring needs**Monitor park glaciers**

Establish a program to monitor glaciers in OLYM. Monitoring protocols from NOCA can be used at OLYM. Park management needs to acquire additional funding to support long-term monitoring of glaciers. From long-term monitoring data, develop a mass balance for glaciers in the park. Also track existing long-term monitoring of park glaciers such as Blue Glacier. (See also Inventory Park Glaciers project description above)

Contact

Jon Riedel, NOCA; jon_riedel@nps.gov, (360) 873-4590 x21

Quantify and determine origin of dust deposition

It is unknown whether global input of dust is being deposited into the park's pristine lakes and streams. It is recommended that dust deposition be monitored at air quality monitoring stations in the park. Quantify air borne sediment deposition and determine dust mineralogy. Dust mineralogy can potentially identify source areas (global vs. local

sources). Dust-capture techniques (dust traps) have been developed for desert environment and should be investigated for use in OLYM.

Contact

(USGS researchers conducting dust studies in arid regions)
Rich Reynolds, USGS; rreynolds@usgs.gov, 303-236-1303

Marith Reheis, USGS; mreheis@usgs.gov, (303) 236-1270

Monitor shoreline and coastal bluff changes

Monitor long-term shoreline and bluff changes using lidar (Light Detecting and Ranging) remote sensing techniques. Lidar can be used for different types of coastal and watershed evaluations (characterize shorelines, hillslopes, channels and vegetation structure) and is a useful tool for landslide mapping. Updated technology may improve on this technique and should be considered when they become available.

In the fall of 2002, the USGS acquired lidar of the West Coast including the coastal areas of OLYM. Contact the USGS for obtaining lidar data and to pursue potential cooperative research using lidar in OLYM. Locally, the Puget Sound Lidar Consortium was established as an effort to pool resources between agencies to defray the cost of lidar and the University of Washington has developed software to process imagery. The park should contact the Puget Sound Lidar Consortium for pursuing cooperative lidar flights to cost share on efforts in the Puget Sound area.

USGS Contact

John Brock, USGS; jbrock@usgs.gov, (727) 803-8747 ext.3088

Reference

Puget Sound Lidar Consortium

website: <http://duff.geology.washington.edu/data/raster/lidar/>

Efforts are also underway to coordinate collaborative investment in getting lidar coverage west side of Peninsula. Washington State Department of Transportation and the tribes are very interested in a collaborative effort.

Contact

Sue Trettevik, Washington State Dept. Natural Resources; (360) 374-6131

Evaluate coastal erosion rates

Evaluate rates of shoreline change in cooperation with the USGS National Coastal Assessment Program for Washington. Washington Department of Ecology has developed digital shorelines from the late 1800's, 1920's and 1950's. Use recently acquired lidar data to create a digital map of the modern shoreline. Determine coastal erosion rates.

Contact

Peter Ruggiero, USGS; pruggiero@usgs.gov, (650) 329-5433

Reference

U.S. National Coastal Assessment, USGS

website: <http://coastal.er.usgs.gov/projects98/7242-33310.html>

Monitor seasonal variations in beach profiles

Carl Schoch is currently assessing seasonal changes along Puget Sound coastlines and has developed a monitoring program using beach profiles and sediment size distribution to determine seasonal variations. Potentially tie beach profiles to lidar mapping and determine net changes of beaches (see also Monitor Shoreline and Coastal Bluff Changes Project).

Contact

Carl Schoch, Kachemak Bay National Estuarine Research Reserve; cschoch@bcc.orst.edu, (907) 235-4799

Establish a groundwater quality monitoring program

Contact NPS WRD to design a groundwater quality monitoring program and protocols for OLYM. Focus monitoring efforts near sewage systems around park facilities and private inholdings. Test for fecal coliforms to determine if septic systems are leaking and affecting groundwater quality.

Contact

Bill Jackson, NPS WRD; bill_jackson@nps.gov, (970) 225-3503

Develop a Water Budget for Lake Ozette and Crescent Lake

Develop water budget for Lake Ozette and Crescent Lake. Monitor lake levels and establish stream gages on major tributaries to the lakes and the outflow/outlet of the lakes.

Monitor Ice Phenology

Establish monitoring of ice phenology (first freeze/first thaw) on park lakes. Monitor the date of first freeze and first thaw for alpine lakes to track the effects of global climate change at OLYM. Investigate the effect of elevation and lake size on this phenomenon.

Evaluate Historic Lake Level Fluctuations in Lake Ozette

Determine historic lake level fluctuations, and evaluate the cause of rising lake levels in Lake Ozette. Study sediment sequence data from lake bottom and sediment fan cores to determine lake level history, fire history, study organic pollutants, sedimentation rates, palynology, and paleo-climate information.

Develop water quality monitoring program

Work with NPS WRD staff to establish protocols for a water quality monitoring program at OLYM and prioritize surface water quality sampling.

Contact:

Bill Jackson, NPS WRD; bill_jackson@nps.gov, (970) 225-3503

Establish channel monitoring program

Establish a long-term channel monitoring program for park streams. NOCA developed protocols to stratify watersheds and select reference sites on a reach level. Document long-term channel changes, channel geometry and bankfull dimensions, pool/riffle attributes, sediment size distribution, large woody debris movement, identify habitat units, and establish photo-points. Also refer to channel monitoring protocols developed by the Timber Fish and Wildlife program.

Contact

(research in stream monitoring)

Dave Montgomery, University of Washington, Earth and Space Sciences Department; dave@ess.washington.edu, (206) 685-2560

Reference

Timber Fish and Wildlife Monitoring Methods Manuals (PDF)

website: <http://www.nwifc.wa.gov/TFW/documents.asp?#mmm>

Establish stream temperature monitoring program

Develop a stream temperature monitoring program in the park to support fisheries management. Evaluate existing stream temperature conditions for salmonids.

Contact

Bill Ehniger, Washington State Department of Ecology; wehi461@ecy.wa.gov, (360) 407-6416

(Potentially interested in maintaining a water temperature probe on a west side river in OLYM)

Establish turbidity monitoring at gaging stations

Develop turbidity monitoring at gaging stations. Share park data with regulatory agencies that address fish and timber issues. Redwood National and State Parks (REDW) is developing protocols for turbidity monitoring and currently has an EPA grant to compare turbidity between disturbed and relatively undisturbed watersheds.

Contact

Randy Klein, REDW; randy_klein@nps.gov, (707) 825-5111

Monitor geothermal springs water quality

Establish a monitoring program for geothermal springs in the park. Determine water quality and chemistry, water temperature, and flow rates.

Evaluate impacts of landuse activities on stream channel habitat

Compare stream channel habitat (pool/riffle habitat, sediment size distribution) impacted by land use adjacent to OLYM with park streams that are relatively undisturbed by human activities. Develop partnerships with local tribes, federal and state agencies, and

private landowners to cooperatively monitor stream channels, standardize protocols between groups, and share resources and data. Tie in with the Timber Fish and Wildlife's Cooperative Monitoring, Evaluation, and Research projects. (See also, establishing channel monitoring program statement)

Monitor channel response to removal of Elwah dam

Two dams on the Elwah River will be removed in the near future. The park has significant concerns about the impact of sediment released from the dam on downstream aquatic resources. An interdisciplinary team of scientists is determining the best course of action to minimize damage to aquatic resources and will identify the best strategies to monitor channel response to removal of the dams. Monitoring of the dam removal will not be addressed in this report.

Track studies on snow pack pollutants

Persistent organic pollutants (pesticides, herbicides, and heavy metals) deposited in the snow pack are washed into lakes and streams through snowmelt and may accumulate or be absorbed into the food chain. Robert Black, USGS, is conducting work on snow pack pollutants. The park should track the results of his studies.

Contact

Robert W. Black, USGS WRD; rwblack@usgs.gov

Reference

Persistent organic pollution and heavy metals in glacial fed lakes and aquatic biota in national parks and forests of the Puget Sound basin.

website: <http://wa.water.usgs.gov/wadmin/Projects/summary.461.htm>

Recommendations for research needs

Study influence of glaciers on aquatic habitat

Evaluate the glacial contribution to stream runoff and summer base flows. Determine the influence of glaciers on the stream aquatic habitat and ecosystems.

Evaluate glaciers as habitat

Relatively little is known about habitat provided by glaciers. Determine what organisms are dependent on glacial habitats. Contact Denali National Park about initial research being conducted on glacial organism (ice worms and spiders).

Higher resolution study of the effect of sea level change on park facilities and developments

Resolution of coastal vulnerability study by USGS in parks may not be sufficient for effective management. Conduct a higher resolution study to evaluate and predict the effect of sea level change over the next 100 years on coastal areas of the park and the impacts to park infrastructure, facilities, and visitor use areas. Identify sections of the coastline more vulnerable to coastal erosion from shoreline changes.

Evaluate hyporheic zones on park streams

The hyporheic zone is biologically active and the area of subsurface water in alluvial floodplain rivers and streams where surface and groundwater mix. It is an important stream ecotone and subsystem that connects river and riparian areas, retains nutrients, and supports a diverse and unique assemblage of invertebrates. The hyporheic zone extends from the streams out into adjacent floodplains. Current research demonstrates that river and streams with hyporheic zones have greater invertebrate communities, retain more nutrients and recover faster from disturbance than rivers without hyporheic zones.

In OLYM, evaluate and map hyporheic zones on park streams. Apply predictive models to analyze terrain features to identify hyporheic zones. Investigate the use of piezometers as a coarse screen to identify upwelling and downwelling zones in streams. Compare the distribution of salmonid spawning related to upwelling and downwelling areas in the streambed.

Contact

Bob Naiman, University of Washington; naiman@u.washington.edu, (206) 685-2025

Rick Edwards, US Forest Service, Juneau; rtedwards@fs.fed.us, (907) 586-8811

References**Description of Hyporheic Zones**

website: <http://www.fish.washington.edu/naturemapping/water/1fldhypo.html>

The Hidden River of Riparian Zones

website: <http://www.cfr.washington.edu/outreach/summit/23Edwards.pdf>

University of Washington Queets River studies focus on the interactions between geomorphic processes, biotic indicators and nutrient cycling in the hyporheic zone.

website: <http://www.fish.washington.edu/people/naiman/Queets/index.html>

Determine effects of seismic events on shoreline position

Evaluate the effects of large subduction zone earthquakes on coastal areas. Identify areas of coastal uplift and subsidence along the coastline.

Determine small catchment hydrologic response to storms

Develop small catchment gaging stations and established nested gages in selected watersheds.

Evaluate effects on engineered structures on stream dynamics

Evaluate the effects of rip rap, barbs, and engineered log jams on channel dynamics both upstream and downstream of sites. Determine if the engineered structures along riverbanks are functioning according to the original objective and determine how they affect fish habitat and utilization.

Determine the effects of altering sediment and large wood delivery to coastal beaches

Quantify the supply of sediment and large woody debris to beaches from coastal watersheds. Determine how alterations in the supply of these materials from land use affects coastal ecosystems. Conduct seafloor mapping to determine nearshore sediment substrate and habitat types. Develop a coastal sediment budget.

Quantify persistent organic pollutants in soils

Persistent organic pollutants (POP, pesticides, herbicides and heavy metals) enter the atmosphere as volatile contaminants and are transported across the landscape by wind currents and eventually deposited in the soil by rain. Determine concentrations of POP's in park soils.

Document coastal elevation change following large earthquakes

Existing coastal lidar data will provide a baseline on which to document coastal uplift and subsidence following the next large Cascadia earthquake. Acquire new lidar data for coastal areas of the park following the next large earthquake.

Evaluate climate change on snow avalanches

Evaluate whether the magnitude and frequency of snow avalanches has changed as a result of climate change from the Little Ice Age to modern climates (i.e., Are modern avalanches smaller and less frequent than those in the Little Ice Age).

Recommendations to Minimize Human Influence**Fine sediment from unpaved roads**

During the summer, dust is generated from vehicles travelling on unpaved dirt roads and can be locally significant. During winter rainfall fine sediment runs off into streams and lakes. Increases in turbidity in streams can be detrimental to aquatic species. Evaluate the potential impacts of fine sediment on stream turbidity from unpaved roads in OLYM. Conduct a literature review on the effects of fine sediment production from unpaved roads. Reid and Dunne (1984) studied fine sediment production from roads in the Clearwater basin, WA. Contact Dr. Reid for more information and protocols for measuring fine sediment contribution from roads.

Contact

Dr. Leslie Reid, U.S. Forest Service; lmr7001@axe.humboldt.edu, (707) 825-2933

References

Reid, L. and Dunne, T., 1984, Sediment production from forest road surfaces: Water Resources Research, v. 20, no. 11, p. 1753-1761.

Reid, L., 1998, Forest Road, Chronic Turbidity, and Salmon, EOS, Abstracts from American Geophysical Union 1998 Fall Meeting, San Francisco, CA.
website: <http://www.rsl.psw.fs.fed.us/projects/water/EOSReid.txt>

Evaluate effects of the jetty at Rialto Beach on coastline

Evaluate the effect of the jetty on coastal processes at Rialto Beach. Determine the history of the jetty and the historic location of the river mouth. Evaluate the affects of the jetty on shoreline processes, and the park's infrastructure and coastal resources.

Determine if point-source pollution of chlorine exists on Sol Duc River

Sol Duc Hot Springs Resort has developed pools heated by geothermal springs. Chlorine is added to the pools every night to address E. Coli contamination. Establish water quality monitoring on the river above and below the hot springs resort to determine if a point-source of chlorine pollution exists and is altering water quality of the Sol Duc River.

Determine visitor impacts on intertidal resources

Evaluate the effects of trampling by park visitors on the intertidal resources. Establish intertidal transects, and inventory intertidal organisms and fish.

Evaluate the impacts of land use on offshore areas

Evaluate the response of coastal areas to sediment pulses from coastal watersheds. Sediment delivery and transport regimes may change on coastal rivers from increased landsliding and causing an increase in sediment delivery to coastal cells. More specifically, evaluate if logging activities in the Quillayute watershed caused sediment deposition offshore of Rialto Beach. Determine if sediment buried and killed kelp beds offshore or prevents the annual recruitment to a more mobile, sandy substrate.

Recommendations for Park Planning**Determine 100 and 500-year floodplains**

Request technical assistance from NPS Water Resources Division (WRD) to determine the 100 and 500-year floodplain for areas in the park with existing and potential future developments. Also look for field evidence of past floods to help validate the results of floodplain modeling.

Contact

Bill Jackson, NPS WRD, Denver, CO; bill_jackson@nps.gov, (970) 225-3503

Improve regression equations for predicting large flow events

Coordinate with the USGS to improve regression equations for predicting large flow events for specific rivers in OLYM.

Apply results of USGS coastal vulnerability study to park planning

Obtain a copy of the final data and report on the National Assessment of Coastal Vulnerability Study to assess the affects of sea level rise on OLYM coastal areas. Evaluate the results of the coastal vulnerability index developed by the USGS to determine the potential risk of current park developments, infrastructure, roads and biological impacts from habitat changes or destruction related to future sea level rise. Results of this study should be incorporated into long-term coastal zone management strategies and planning such as the General Management Plan. Provide products from this

study to local tribes and Federal and State agencies managing coastal areas. This study is a cursory evaluation of coastal vulnerability to sea level rise and should be followed up with a more detailed/high resolution study in OLYM (see research recommendation for higher resolution study on the effects of sea level change).

Contact

Erica Hammar-Klose, USGS; ehammark@usgs.gov; (508) 548-8700

Reference

National Assessment of Coastal Vulnerability Study

Thieler, E.R., and Hammar-Klose, E.S., 2000, National Assessment of Coastal Vulnerability to Future Sea-Level Rise: Preliminary Results for the U.S. Pacific Coast, U.S. Geological Survey, Open-File Report 00-178, 1 sheet.

website: <http://pubs.usgs.gov/openfile/of00-178/>

website: <http://woodshole.er.usgs.gov/project-pages/cvi/>

Fact Sheet - National Assessment of Coastal Vulnerability to Future Sea-Level Rise

website: <http://pubs.usgs.gov/factsheet/fs76-00/>

Address seismic hazards in future planning

Future park planning (including emergency plans) should address seismic hazards. Insure future developments and facilities will adequately address earthquake and tsunami issues, and are not located in areas prone to ground failure, rupture, liquefaction, or tsunami inundation zones, and built to current seismic standards. Incorporate earthquake and tsunami planning issues into the OLYM General Management Plan.

Identify tsunami inundation and evacuation zones

The coastal areas of OLYM are at risk from locally generated or a distance source tsunami. Identify the tsunami run up zone for coastal areas and establish evacuation routes. Provide public education on coastal hazards.

List of Participants

Olympic National Park

Bill Baccus, Administrative Officer
Cat Hoffman, Resource Management Division Chief
John Meyer, Fish Biologist, Port Angeles
Michael Smithson, Resource Education Division Chief
Kathy Steichen, Supervisory Education Specialist?

National Park Service

Steve Acker, Regional Inventory and Monitoring Coordinator, Seattle, WA
Rebecca Beavers, Geologic Resources Division, Denver, CO
Sid Covington, Geologic Resources Division, Denver, CO
Marsha Davis, Columbia Cascades Support Office, Seattle, WA
Rick Harris, Office of Strategic Planning, Denver, CO
Bob Higgins, Geologic Resources Division, Denver, CO
Vicki Ozaki, Redwood National and State Parks, Arcata, CA
Steve Ralph, Network Inventory and Monitoring Coordinator, Seattle, WA
Jon Riedel, North Cascades National Park, Sedro Woolley, WA
Mathew Safford, Denver Service Center, Denver, CO

United States Geologic Survey

Erika Hammar-Klose, Woods Hole, MA
Sam Johnson, Denver, CO
Mark Mastin, Tacoma, WA
Peter Ruggiero, Menlo Park, CA
Randy Schumann, Denver, CO
Ed Schreiner, Port Angeles, WA
Rowland Tabor, Menlo Park, CA

Washington State

Wendy Gerstel, Dept. of National Resources, Olympia, WA

Appendices

- A. Descriptions of 27 Geoindicators
- B. Human Influences
- C. Introducing Geoindicators
- D. Species Don't Stand Alone – Geology's Role and Importance in Ecosystems
- E. Compilation of Notes from Geoindicator Scoping Session

Appendix A. Description of 27 Geoindicators

Appendix B. Human Influences

Appendix C. Introducing Geoindicators

Appendix D. Species Don't Stand Along- Geology's Role and Importance in the Ecosystems

Appendix E. Compilation of Notes from Geoindicator Scoping Discussion

Glacial and Periglacial Processes

Frozen Ground Activity

Background

Periglacial features and processes influence natural and managed ecosystems, including forests, grasslands and rangelands, mountains and wetlands, and their hydrological systems. The freezing and thawing of soils and surficial materials and the consequent ground changes are natural processes controlled by climatic, geomorphic, and geologic conditions, and can be modified by human actions in and around settlements, recreation sites/corridors, and engineering works. The freeze/thaw processes of the periglacial environment can result in serious and costly disruptions from ground subsidence, slope failure, icings, and other cryogenic processes.

Where there is extensive seasonal freezing and thawing of soils, a wide range of processes lead to a variety of sensitive periglacial features. Frost heaving is a physical process associated with near surface winter freezing and can displace buildings, roads, pipelines, drainage systems, and other structures. Thermal contraction in rock or frozen ground with substantial ice content can form patterned ground, such as stone stripes or stone polygons, and these features are extremely sensitive to human disturbance. Gelifluction occurs on slopes where daily and seasonal cycles of freezing and thawing slowly moves soil downslope. Landscapes with active gelifluction can create significant engineering and maintenance problems for facilities, roads, trails, and septic systems.

Points of Discussion

Season freezing and thawing occurs in the high alpine areas of the park. Gelifluction lobes are an active geologic processes in Olympic National Park (OLYM). Patterned ground (stone stripes and stone polygons) are unique features of the high country and exist on old erosion surfaces in the high alpine areas. Patterned ground is a fragile environment that is easily disturbed by human activity and foot traffic. Once disturbed it requires extremely long recovery times.

- Patterned ground is not only a relic feature, but more information and data are needed to determine which of these features are currently active, and how they form.
- Obstruction Point on the northeast side of park is one of the few high country areas with road access. It is a popular visitor site with high use, fragile geologic features, and a high numbers of endemic plants. It is unknown if visitors are disturbing patterned ground in this area.
- The park has mapped plant associations between the occurrence of patterned ground and the distribution of endemic plants.
- This geoindicator was rated high for its importance as a natural process to park ecosystems because of the high number of endemic plants associated with areas of seasonal freeze/thaw.

- Human influence on this geoinicator is considered moderate to high. Currently there is no monitoring of human impacts on this resource.

Recommendations

- Map distribution of patterned ground and gelifluction lobes in the park. Focus on areas around roads and trails.
- Need baseline information on patterned ground for Lillian Ridge and Blue Mountain to assess visitor impacts on the resources. Establish photo-point monitoring. Assess information from historic photos. Map features from good aerial photography.

Glacier Fluctuations

Background

Glaciers grow or diminish in response to natural and potential human-induced climatic fluctuations. They record annual and long-term changes and are practically undisturbed by direct human actions. Their capacity to store water for extended periods exerts significant control on the surface water cycle. Glacier advances, the length of mountain glaciers and their ice volume has decreased throughout the world during the past century or two, providing strong evidence for climate warming. Changes in glaciers can exert profound effects on the surrounding environment. The advance and retreat of mountain glaciers creates hazards to nearby human structures and communities through avalanches, rockfalls and debris flows, and catastrophic outburst floods from ice and moraine-dammed lakes. The location of the terminus and lateral margins of glaciers also exerts an influence on nearby physical and biological processes.

Points of Discussion

Glaciers are a key feature of the park and are a highly valued resource by the visiting public. Glaciers are very important to the park's ecosystems; they provide a source of water and buffer the streams from organochlorides.

- Jon Riedel is developing monitoring protocols for glaciers at North Cascades National Park (NOCA) and protocols could be applied at OLYM. MORA glaciers are larger and crevasses inhibit access. Mount Rainer National Park (MORA) needs to develop separate protocols from NOCA.
- Climate change over the next 100 years will have a significant affect on glaciers. Need long-term study of OLYM glaciers to document changes, also incorporating historic information.
- Cat Hoffman and Jon Riedel developed a proposal for glacier monitoring at OLYM but have limited funds and personnel.
- Researchers at the University of Washington are studying glaciers as a trap for pollution. Dust and pollutants, deposited in ice cores, are flushed when glaciers melt. Need to identify study areas and track the results of these studies.
- Human influence is considered high to moderate because global climate change has both a natural and anthropogenic component. Human impacts are indirect.
- Management issue is considered high. Glaciers are a key feature of the park and highly valued by the public.

Recommendations

- Inventory: Use satellite photography for complete inventory of all park glaciers. Consider reinventorying glaciers every ten years.
- Monitor: Monitor glaciers in OLYM. Need additional funding to support long-term monitoring of glaciers at OLYM. Develop a mass balance for glaciers. Check on available satellite imagery for use in mapping glaciers.
- Research: A new research topic is glaciers as habitat. Glaciers provide habitat to organisms. Ice worms and spiders inhabit glaciers. DENA beginning to work on glacial organisms. Research: Link glacier observations to contributions of runoff for ecological impacts. Need to understand how glaciers are tied to aquatic systems.
- Research: Study the relationship between glaciers and aquatic habitat in streams. Evaluate the contribution of runoff from glaciers (especially to summer base flows) and the influence on stream aquatic habitat.

Aeolian Geoindicators

Dust Storm Magnitude, Duration and Frequency

Background

Local, regional, and global weather patterns can be strongly influenced by accumulations of dust in the atmosphere. Fine particulate matter in the atmosphere creates a nucleus for precipitation and snow. While, dust storms are a mechanism to transport sediment and are natural events, the amount of sediment available for transport may be increased by human disturbances such as overgrazing, road construction, farming, or removal of vegetation. Dust storms can remove large quantities of surface sediments and topsoil. Material picked up from other continents can be transported in the atmosphere across the oceans and deposited locally. In China, farming of marginal lands has created significant soil disturbance. As a result, dust storms in that region are more frequent than past times and can potentially affect the amount of fine particulate matter in the atmosphere at a global scale.

Points of Discussion

At this time there is not enough information to evaluate the impacts of dust deposition on ecosystems at OLYM. More information is needed to determine if this is an issue and if the air borne sediment is from a local or global source.

- Local Issue: During the summer, dust is generated from vehicles travelling on unpaved dirt roads and can be locally significant. Dust coats vegetation and creates fine sediment that runs off into streams and lakes during winter rainfall. Increases in turbidity in streams can be detrimental to aquatic species. Some examples of heavily used unpaved roads that generate dust are the Quinault Loop Road and Obstruction Point (on the west side of the park) and Staircase, and Dosewallips (on the east side). Removal of the Elwha dam in 2004 may also locally increase dust deposition.

- Management significance is moderate. Reducing fine sediment from roads entering streams is a park road maintenance issue.
- Dust from Asia and other global sources may reach the Olympic Peninsula. Dr. Bob Edmonds, University of Washington, has been monitoring biochemistry of small watersheds on the Olympic Peninsula and a monitoring station has picked up an anomalous nitrogen spike. It is speculated that air borne sediment from a global source may be the cause for the spike. The park may need to sample more isolated lakes to determine if air borne sediment from global sources are impacting park resources.
- On a local scale, dust is produced by human activities and human influence is considered high for this geoindicator.
- This geoindicator is considered low to moderate for park management.
- USGS researchers are studying dust deposition in the southwest. USGS has developed different sampling techniques and protocol for capturing dust. In general, do not sample dust deposition on the ground. Establish sampling site 2-3 m off the ground. Some sampling techniques discussed include: 1) cake pan with marbles, 2) airfoil with a glass plate and Vaseline to capture blowing material and, 3) dry deposition bucket with cover that closes in event of rain.

Recommendations

- Contact NPS Air Quality Division about monitoring dust deposition.
- Place dust traps at air quality monitoring stations. Consider also sampling more isolated lakes to determine if air borne sediment from global sources are impacting park resources. Determine mineralogy of dust to determine potential source areas.
- Evaluate Leslie Reid's publication on quantifying fine sediment contribution from roads at OLYM. Conduct a literature search for more current published studies. Determine if fine sediment production from unpaved roads might be an issue to aquatic ecosystems in the park and if it merits monitoring.

Wind Erosion

Background

The action of wind on exposed sediments and friable rock formations causes erosion and entrainment of sediment and soil particles, as well as forms and shapes sand dunes and other landforms. Wind can reduce vegetation and expose subsurface deposits and plant roots. Wind erosion is a natural phenomenon, but the surfaces it acts upon may be made more susceptible to wind erosion by human actions that result in the reduction of vegetative cover.

Points of Discussion

Wind erosion is of only limited significance at OLYM.

Recommendations

No recommendations.

Coastal Geoindicators

Relative Sea Level

Background

Changes in Relative Sea Level (RSL) may alter the position and morphology of coastlines, causing coastal flooding, water-logging of soils, bank/bluff retreat and reactivation of deep-seated landslides, and a loss or gain of land. Changes in relative sea level may also create or destroy coastal wetlands and salt marshes, inundate coastal settlements, and induce saltwater intrusion into aquifers, leading to salination of groundwater. Coastal ecosystems are bound to be affected, for example, by increased salt stress on plants. A changing RSL may also have profound effects on coastal infrastructure and communities.

Points of Discussion

OLYM manages over 60 miles of coastline. Although it is predicted that sea level will rise 15-90 cm within the next 100 years, the anticipated sea level rise of 1.9 mm/yr will be offset by the anticipated 1.8 mm/yr eustatic rise at OLYM (concentrated inland within the core of the Olympic Mts). The coastal areas are not being uplifted as rapidly as inland and it is unknown what the relative rise in sea level will be at OLYM. El Nino events are shorter duration events that cause high water level fluctuations and are a greater concern for OLYM than RSL. During El Nino years, coastal erosion may be accelerated. Also up to 1.5 m of subsidence (or uplift) may occur along coast strip during large Cascadia subduction events causing considerable alteration of the coast and change in shoreline configuration.

- The USGS Coastal and Marine Geology Program has been evaluating the vulnerability of coastal lands to sea level rise. The nationwide coastal vulnerability to sea level rise assessments was completed at 3-minute resolution. The 1-minute resolution in parks may not be sufficient for effective management. Additional shoreline change data are needed.
- An initial USGS coastal vulnerability map for OLYM has been completed and was ground-truthed by Erika Hammar-Klose. Mapping provides a cursory evaluation of risk. When the mapping is finalized by the USGS, it will serve as a good GIS layer for park planning and management.
- Rates of shoreline change (based on 1950's and 1920's data) indicate that portions of the Olympic shoreline are undergoing about 1 m of erosion or accretion per year.
- River mouths, estuary settings and other low elevation areas are at highest risk.
- Tectonics was not included in analysis of RSL.
- Tide gage data is collected at Neah Bay, WA.
- No agreement exists with Washington Department of Natural Resources to allow the park boundary to be changed/moved as coastline moves eastward through coastal erosion.
- Curt Peterson, Oregon State University, potentially has a coastal landform/geomorphology GIS layer, air photos and elevation data. Contact him about the availability of his coastal data.

Recommendations

- Planning: Obtain a copy of final data for the USGS National Assessment of Coastal Vulnerability Study in OLYM to assess future sea level rise. Evaluate the results of the study to determine the potential risk of current park developments, infrastructure and roads to future sea level rise. Use information in OLYM General Management Plan process to evaluate coastal park developments. Provide information products from USGS study to local tribes and Federal and State agencies managing coastal areas.
- Research: Conduct higher resolution study predicting the effects of RSL on OLYM coastal areas, incorporating geodetic data and tectonic studies (Brandon and Pazzaglia).

Shoreline Position

Background

The position of the shoreline along ocean coasts and around lakes varies over a broad spectrum of time scales in response to shoreline erosion (retreat) or accretion (advance), changes in water level, and land uplift or subsidence. Long-term trends in shoreline position may be masked in the short term by variations over periods of 0.1 to 10 years or more, related to individual storms, change in storm frequency and magnitude. Shoreline position reflects the coastal sediment budget and changes may indicate natural or human-induced effects along shore or in nearby watersheds. The detailed shape and sedimentary character of a beach are highly sensitive to ocean influences, including deep-water wave energy, nearshore wave action, storm surge, and nearshore circulation, as well as anthropogenic influences such as jetties, bulkheads, etc. Dynamic shoreline adjustments and feedback are common. Changes in shoreline position can affect transportation routes, coastal installations and facilities, communities, and ecosystems.

Points of Discussion

The park manages about more than 60 miles of shoreline. Changes in shoreline position have the potential to significantly impact the parks' tideland areas.

- Coastal structures and infrastructure within the park that would be affected by shoreline changes include: the jetty at Rialto beach, pilings along the coast at Klahloch Lodge and the trailhead at Beach Trail.
- Changes in shoreline position may be caused by accelerated sediment production from landuse (logging and road building) in coastal watersheds.
- Changes in runoff from the highway, roads, campgrounds, and parking lots may affect coastal slope stability and in turn effect shoreline position.
- Tribe was monitoring the gravel barrier at Rialto Beach. A winter storm in 1994 punched a hole in the gravel barrier. The local Congressman got appropriation to address the issue. Army Corps of Engineers was able to pull together a quick and dirty Environmental Assessment with a pre-selected alternative. Hybridized the preferred alternative to include jacks with rip rap and lined the barrier with rock. The gravel barrier is a dynamic feature that is periodically destroyed and rebuilt.

- Sediment is dredged at Rialto beach and deposited on the north side of the jetty.

Recommendations

- **Monitor:** Evaluate shoreline change in cooperation with the USGS (national shoreline assessment program). Washington Department of Ecology has developed digital shorelines from late 1800's, 1920's and 1950's. Need to develop a modern shoreline map.
- **Inventory and Monitor:** Inventory and monitor the distribution and volume of large woody debris along the coast, and upstream on major tributary rivers, over time. Studies in Oregon by Oregon State University and Pacific Northwest Research Station, USDA Forest Service document the importance of large woody debris in estuarine and oceanic habitats.
- **Inventory and Monitor:** Determine the quantity, location and quality of nearshore habitats (intertidal and shallow subtidal areas) and use to guide long-term land use planning and developments in coastal areas. An inventory would include both biological and physical components of the intertidal areas and this project is ideally suited to vital signs monitoring. Develop baseline data of geomorphic habitat characterizations for biological communities and establish long-term trend monitoring of selected sites.
- **Monitor:** Monitor Seasonal Changes in Beach Profiles. Carl Schoch is currently assessing seasonal changes along Puget Sound coastlines and has developed a monitoring program using beach profiles and sediment size distribution to determine seasonal variations. Potentially tie beach profiles to lidar mapping and GIS data and determine net changes of beaches.
- The USGS Center for Coastal Geology and Marine Studies oversees a program that generates lidar data for coastal areas of the lower 48 states on a three-year cycle. Lidar of the West Coast of the U.S. will be flown in the fall of 2002.
- Evaluate the effect of the engineered structure on the coastline at Rialto Beach. Determine the history of the jetty, the affects on shoreline processes and associated impacts to park infrastructure and natural resources.
- **Research:** Coastal vulnerability from storm cells for coastal bluff erosion. (see recommendation for research on mechanisms for coastal bluff failure under slope stability geoinicator)

Dune Formation & Reactivation

Background

Coastal dunes are important determinants of coastal stability; supplying, storing and receiving sand blown from adjacent beaches. Dunes develop under a range of climatic and environmental controls, including wind speed and direction, moisture, and sediment availability. Widespread changes can be induced by changes in wind patterns and by human disturbance, such as alteration of beach processes and sediment budgets, destruction of vegetation cover by trampling or vehicle use, overgrazing, and the introduction of exotic species. Moving dunes can engulf houses, facilities, developments and road systems. Dunes play an important role in many ecosystems (boreal, semi-arid,

desert, coastal) by providing morphological and hydrological controls on biological gradients.

Points of Discussion

Dunes in OLYM are limited to a small area along the coast near the mouth of the Kalaloch River.

- Small active dunes near the Kalaloch River help provide some protection of the bluffs.
- Shorelines are more sandy to the south of Beach 4 along the Olympic coast.
- To the north of Ruby beach more gravel beaches are present between rocky headlands.
- Many areas that might contain dunes are also covered with large logs (i.e. Kalaloch Lodge).

Recommendations

No recommendations.

Groundwater Geoindicators

Groundwater Quality

Background

Groundwater is globally important for human consumption and use, and changes in quality can have serious consequences. It is also important to support terrestrial and aquatic habitat and for maintaining the base flow in rivers and springs. The chemical composition of groundwater is a measure of its suitability as a source of water for human and animal consumption, irrigation, and for industrial and other purposes. Groundwater quality also influences ecosystem health and function, so that it is important to detect early warning of changes in natural systems, and human caused contamination (pollution).

Points of Discussion

During the meeting at OLYM, the scoping group discussed in-depth the hyporheic zone as part of the groundwater quality geoindicator. The rankings are based on the importance of the hyporheic zone in streams. Additional issues in ground water quality were also discussed under the groundwater chemistry in the unsaturated zone geoindicator.

- OLYM relies on surface water as a water source and doesn't extract groundwater except for the use of springs at Hurricane Ridge.
- Land management and logging practices adjacent and outside the park impact surface water quality and groundwater quality.

Hyporheic Zone

The hyporheic zone is biologically active and the area of subsurface water in alluvial floodplain rivers and streams where surface and groundwater mix. It is an important stream ecotone and subsystem that connects river and riparian areas, retains nutrients, and supports a diverse and unique assemblage of invertebrates. The hyporheic zone extends from the streams out into adjacent floodplains. Current research demonstrates that river and streams with hyporheic zones have greater invertebrate communities, retain more nutrients and recover faster from disturbance than rivers without hyporheic zones.

References:

Description of Hyporheic Zones

University of Washington and the NatureMapping Program of Washington

website: <http://www.fish.washington.edu/naturemapping/water/1fldhypo.html>

University of Washington College of Forest Resources

website: <http://www.cfr.washington.edu/outreach/summit/23Edwards.pdf>

- Dr. Bob Naiman, Rick Edwards, and graduate students are working on research in hyporheic zone on the Queets River. The studies focus on the interactions between geomorphic processes, biotic indicators and nutrient cycling.
<http://www.fish.washington.edu/people/naiman/Queets/index.html>
- It is suspected that the hyporehic zone is very important to bull trout, but it is unknown at this time.
- Humans can influence hyporheic zone. Logging and road building can cause deposition of fines in the streambed and alter function of the hyporheic zones.
- Larval insects feed on unique biota in the hyporehic zone. Groundwater test wells 2 km away from the Swan River and Flathead River, Montana contained aquatic invertebrates.

Recommendations

- Monitor: Develop groundwater quality monitoring program in OLYM. See also recommendations in section on Groundwater chemistry in the unsaturated zone geosindicator.
- Research: Evaluate and map hyporheic zones on park streams. Apply predictive models to analyze terrain features to identify hyporheic zones. Investigate the use of piezometers as a coarse screen to identify upwelling and down welling zones in streams. Compare the distribution of salmonid spawning related to upwelling and downwelling areas in the streambed.

Groundwater Chemistry in the Unsaturated Zone

Background

Water moves downward through porous soils and sediments and, under favorable conditions, may preserve a record of weathering processes, climatic variations, or human activities such as agriculture and acidification. This indicator may be considered as the output from the soil zone and may reflect the properties or change in properties of soils.

The unsaturated zone is also an important buffering zone for attenuation of acidity, metal content, and some other harmful substances. The unsaturated zone may store and transmit pollutants, the release of which may have a sudden adverse impact on groundwater quality.

Points of Discussion

At OLYM, the unsaturated zone not a prevalent feature.

- Inholdings along Lake Crescent have septic systems. The park has measured significant algae blooms at the outlet to Lake Crescent and is a significant concern to park management. Algae is a marker for human pollutants (bacterial). The lake is usually oligotrophic.
- Pollutants in runoff from roads and parking lots may affect groundwater chemistry. Need to potentially monitor water chemistry of parking lots.
- Underground storage tank at Kalaloch Lodge has leaked oil.
- Transformers stored in the flood plain of the Elwah River leaked PCB's and contaminated the floodplain and surface water.
- Hurricane Ridge – Sewage is disposed of in an evaporation field. It is an antiquated system and sewage is held in a holding tank until dumped. System backs up and the tank needs to be emptied more frequently. OLYM needs a new sewage treatment system.
- Quinault Visitor Center is on a septic system.
- Private inholdings have septic and a variety of systems. High use areas are on park lakes and probably discharge into lake.
- Maintenance conducting park-wide inventory of sewage disposal systems.
- Human impacts and management significance were high in specific locations. Septic system issues in developed zones like Crescent Lake are a high concern to the park.
- Park management limit use at South Beach because of the capacity of septic system.
- Surface water from the Kalaloch Creek is pumped to supply water for the Kalaloch Lodge. Water is returned from sewage treatment facility back to the creek.

Recommendations

- Inventory: Contact NPS, Water Resources Division to design a groundwater quality monitoring program and protocols for OLYM. Focus monitoring near sewage systems around park facilities and private inholdings. Test for fecal coliform to determine if septic systems are leaking.

Groundwater Level

Background

Groundwater is the major source of water in many regions, supplying a large proportion of water globally. In the USA, more than half the drinking water comes from the subsurface: in arid regions it is generally the only source of water. The availability of clean water is of fundamental importance to the sustainability of life. It is essential to know how long the resource will last and to determine the present recharge: groundwater mining is a terminal condition.

Points of Discussion

Groundwater level is not as much of a problem at OLYM because of the high annual rainfall and the lack of groundwater extraction. The park relies primarily on surface water for water supply to parks.

Recommendations

No recommendations.

Surface Water Geoindicators

Lake levels

Background

Lakes are dynamic systems that are sensitive to local climate and to land-use changes in the surrounding landscape. Some lakes receive their water mainly from precipitation, some are dominated by drainage runoff, and others are controlled by groundwater systems. On a time scale ranging from days to millennia, the areal extent and depth of water in lakes are indicators of changes in climatic parameters such as precipitation, radiation, temperature, and wind speed. Lake level fluctuations vary with the water balance of the lake and its catchment, and may, in certain cases, reflect changes in shallow groundwater resources. Lakes without outlets are especially useful as climatic indicators.

Points of Discussion

OLYM has many small alpine lakes. Little is known about high alpine lakes and fluctuations in lake levels. The two largest lakes in the park are Ozette Lake in the coastal strip of OLYM and Crescent Lake on the northern boundary of the main park. These lakes are not located in the wilderness areas.

- Exotic eastern brook trout were stocked in high mountain lakes before it was realized that this management practice impacted native aquatic species.
- Robert W. Black (USGS-WRD) is conducting work on snow pack pollutants. Persistent organic pollutants (pesticides, herbicides, and heavy metals) in the snowpack are washed into lakes and streams through snowmelt and may accumulate or be absorbed into the food chain.

Contact: Robert W. Black, e-mail- rwblack@usgs.gov <rwblack@usgs.gov>

Project Summary: Persistent Organic Pollution and Heavy Metals in Glacial Fed Lakes and Aquatic Biota in National Parks and Forests of the Puget Sound Basin
<http://wa.water.usgs.gov/wadmin/Projects/summary.461.htm>

Lake Ozette:

- Lake Ozette is the largest lake in the park and the third largest lake in the State of Washington.

- All tributaries that drain into Lake Ozette are private lands primarily in timber production.
- Lake supports chinook, sockeye, coho, and chum salmon, steelhead and cutthroat trout and a number of resident non-salmonid species.
- The Lake Ozette Sockeye salmon population is one of the only remaining stocks in the State of Washington and was federally listed as Threatened in 1999 as part of the Ozette Lake Evolutionary Significant Unit.
- Sockeye salmon spawn along the shallow beaches. The two principal shoreline spawning beaches for Ozette sockeye salmon are Olsens' Beach (or Olsen's Landing), north of Siwash Creek on the lake's eastern shore and the beach area north of Allen's Bay on the lake's western shore of the lake.
- Tributaries to Lake Ozette generally have high turbidity in the winter and high water temperatures in the summer.
- Lake level fluctuates annually up to 9 ft per year. Fluctuations in the lake level effect salmon spawning grounds and are very important for shoreline spawning salmon populations. Some years the lake levels drop quickly and isolate spawning redds.
- For last two years park rangers have been recording daily lake level elevations and rainfall.
- Timber harvest and road building have been cited as contributing to the decline of salmon spawning beds by causing siltation of salmon spawning beds in tributaries and along beach shorelines. Sediment eroded from tributaries is deposited in the lake and a delta has built up at the mouths of tributaries. As a result, the sediment composition of the lakebed is changing. Introduced exotic plant, canary reed grass is colonizing in finer sediment rich areas along lake shorelines. For example, in 1989 sockeye salmon used the beach near Umbrella Creek for spawning. Currently no spawning occurs on the beach because the gravels are buried under a layer of fine sediment.
- Lake Ozette is lower than sea level and the lake is located about three miles from the coast. May be susceptible to salt water intrusion.
- Change in hydrologic control of lake outlet. Outlet of lake was purged of all large wood. Currently, a large debris jam is blocking the outlet and causing the lake level to rise. The large woody debris is thought to be from logging.
- National Marine Fisheries Service recovery planning efforts for Lake Ozette sockeye salmon are currently underway.

Recommendations

- Monitor: Develop water budget for Lake Ozette and Crescent Lake. Monitor lake levels and establish stream gages on major tributaries to the lakes and the outflow/outlet of the lakes.
- Monitor: Develop a monitoring program for ice phenology on park lakes. Determine the date of first freeze and first thaw for alpine lakes. Investigate the effect of elevation and lake size on this phenomena.
- Inventory: Inventory all small alpine lakes in the park. NOCA is a prototype park for developing monitoring protocols and OLYM should consult with NOCA on inventory protocols.

- Inventory: Identify sediment sources in tributaries associated with increased sediment transport to Lake Ozette and quantify the sediment impacts from adjacent private lands on Ozette Sockeye spawning gravels.
- Research: Determine historic lake level fluctuations and evaluate the cause of rising lake levels in Lake Ozette. Core lake bottom and fan sediments to determine lake level and sedimentation history.

Surface Water Quality

Background

Surface water quality is highly important to ecosystems since clean water is essential to all living organisms. The quality of surface water in rivers and streams, lakes, ponds and wetlands is determined by interactions with soil, transported solids (organics and sediment), underlying geology, groundwater and the atmosphere. Surface water quality may be significantly affected by agricultural, industrial, urban and other human actions, as well as by atmospheric inputs.

Points of Discussion

- Human impacts to surface water quality in OLYM is considered moderate and includes: sediment from logging and road building activities, surface runoff from parking lots, oil spills from offshore shipping lanes, and septic tanks.
- Currently, no parkwide surface water quality monitoring. No testing for Giardia in park streams.
- Need baseline water quality data for park and staff to implement program.
- OLYM has worked with NPS WRD on site-specific surface water quality projects.
- Will be hiring an aquatic ecologist. Person will develop ecosystem-based information to support fishery management.
- Water temperature is monitored for a few coastal creeks.
- Park management focuses primarily on sediment and temperature impacts to fish and on septic systems impacts around lakes.
- Park management significance was considered moderate to high for this geoinicator.

Recommendations

- Monitor: Develop a water quality monitoring program for OLYM. Work with NPS Water Resources Division staff to establish protocols and prioritize surface water quality sampling.
- Monitor: Establish stream temperature monitoring program in the park to support management of aquatic and fisheries resources. Evaluate stream temperature conditions for salmonids.

Streamflow

Background

Streamflow is an important geoinicator because streams respond rapidly to changes in an ecosystem. Streamflow directly reflects climatic variation. Stream systems play a key

role in the regulation and maintenance of biodiversity. Changes in streams and streamflow are indicators of changes in basin dynamics and land use.

Points of Discussion

Winter flooding occurs nearly every year on park streams. Flooding has affected park trails, bridges and roads. In 1999, OLYM had 22 inches of rainfall in 24 hours and flooding significantly affected park infrastructure.

- USGS monitoring discharge on the major rivers in OLYM. Good long-term discharge records exist for larger streams in OLYM, but not for smaller streams.
- Hydrology of small catchments is not monitored by the USGS. Need baseline data for small catchments in OLYM to support aquatic and fish studies. Determine the hydrologic response of small watersheds to storms. Synthetic hydrographs were developed to estimate peak flow for the State of Washington.
- Need to design study to monitor flow data on coastal streams.
- Human influences on streamflow includes: alteration of stream channel geometry from logging and road building activities; runoff from paved roads; alteration of flows by dams.
- Two dams on the Elwah River affect stream discharge.
- Road issues along Finley Creek

Recommendations

- Technical assistance: Request technical assistance from NPS Water Resources Division to determine the 100 and 500 year flood mapping for areas of the park with existing and potential future development. Also look for field evidence of past floods.
- Monitor: Determine small catchment hydrologic response to storms. Develop gaging stations and established nested gages in selected watersheds. Create synthetic hydrographs.
- Coordinate with the USGS to improve regression equations for predicting large extreme events for specific rivers in OLYM.

Stream Channel Morphology

Background

Channel dimensions reflect magnitude of water and sediment discharges. An understanding of stream morphology can help delineate environmental changes of many kinds. Changes in stream pattern can alter aquatic and riparian habitat.

Points of Discussion

- Stream channel morphology is very important to parks aquatic and riparian ecosystems
- Human influences on channel morphology on streams in OLYM include: rip rap, engineered log jams, bridges, gravel mining adjacent to park boundaries, logging, dams.
- Cushman Dam is located outside the park boundary but influences the flow, sediment transport and channel morphology of the North Fork Skokomish River in the park.

- Gravel mining occurs on several streams outside of the park boundary and alters channel morphology.
- Elwah Dam will be removed in the near future. Currently a team of scientist evaluating the best restoration alternatives and developing monitoring strategies.
- NMFS for Section 7 consultation is inventorying rip rap within and outside of the park. NMFS will evaluate the threshold at which rip rap will be considered a take on federally listed fish species. Coho spawn above and below rip rap in the rivers. It appears that velocities are so high that it mobilizes the substrate and erodes out eggs/redds deposited in the streambed. Rip rap also captures the thalweg (deepest part of the channel), cuts off recruitment of large woody debris, can deflect stream energy and cause erosion downstream. Rip rapped banks also generally offer no shade which may influence stream temperatures. Currently, a higher percentage of the Hoh River is rip rapped within the park than outside the park boundaries. There are similar issues on the Quinault River. The county and state are grappling with a similar rip rap consultation issue.
- A couple engineered log jams have been placed on the Hoh River and have not been evaluated.
- Human influence is considered high on channel morphology geindicator.
- Park management is involved in many issues related to channel morphology and management significance to the park is considered high.
- Jim O'Connor has conducted studies on Salmon River and similar protocols may be used at OLYM. He has also worked on projects on several streams in and adjacent to the park.
Contact: Jim O'Connor, USGS; occonnor@usgs.gov
- USGS staff at Cascade Volcanic Observatory has conducted research on streams draining Mt St Helen's to determine how sediment loading has affected stream channel morphology.

Recommendations

- **Monitoring:** Establish a long-term channel morphology monitoring program for park streams. NOCA developed protocols to stratify watersheds and select reference sites on a reach level. Document long-term channel changes, channel geometry and bankfull dimensions, pool/riffle attributes, sediment size distribution, identify habitat units, and establish photo-points. Refer to channel monitoring protocols developed by the Timber Fish and Wildlife program.
- **Research:** Evaluate the effects of rip rap, barbs, and engineered log jams on channel dynamics both upstream and downstream of sites. Determine if the engineered structures along riverbanks are functioning according to the original objective and determine how they affect fish habitat and utilization.
- Provide better integration of stream science (fisheries, plant ecology, hydrology, stream morphology, and habitat).

Stream Sediment Storage and Load

Background

Sediment load (suspended and bedload) determines channel shape, pattern, and morphology. Changes in sediment yield reflect changes in basin condition, including climate, soils, erosion rates, vegetation, topography and land use. Fluctuations in sediment discharge affect many terrestrial, stream, and coastal processes. Changes in sediment transport can also influence ecosystem responses, because nutrients are transported with the sediment load. For example, to reproduce effectively, salmon and trout need clean streambed gravels for spawning and egg survival; sand and silt deposited on the streambed can reduce intergravel flow and kill developing eggs. Channel bed scour during winter flows can scour out redds and likewise, excessive sediment deposition can bury and destroy spawning beds. Refer also to the discussions for slope failures and soil and sediment erosion geosindicator.

Points of Discussion

- Human influences on stream sediment storage and load include: timber harvesting and road building altering erosion and deposition in streams, and dams on several park streams affect sediment storage and load.
- Human activities have a high influence on sediment storage and load in OLYM.
- Sediment transport and storage is important to coastal ecosystems. The size of sediment and the amount can affect and change intertidal fauna. Plumes of sediment from nearby coastal streams can also reduce the prey base in coastal areas.
- Logging of the Quillayute River near Rialto Beach has caused an increase in sediment transport and load and has altered the stream channel and nearshore environment. The river and the harbor have aggraded and as a result channels in Rialto Harbor are dredged.
- Sediment load and storage is a high management concern.

Recommendations

- Research: Quantify the supply of sediment and large woody debris to beaches from coastal watersheds. Determine how alterations in the supply of these materials from land use affects coastal ecosystems. Develop a coastal sediment budget.

Wetland Extent, Structure and Hydrology

Background

Wetlands are areas of high biological productivity and diversity. They provide important sites for wildlife habitat and human recreation. Wetlands mediate large and small-scale environmental processes by altering downstream catchments. Wetlands can affect local hydrology by acting as a filter, sequestering and storing heavy metals and other pollutants, and serving as flood buffers and, in coastal zones, as storm defenses and erosion controls.

Points of Discussion

OLYM contains a diversity of the wetland types throughout the park; lowland, coastal bogs, alpine to sub-alpine wetlands. However there is limited information on the wetland resources in the park.

- Wetlands are an important component of the ecosystem.
- Need basic comprehensive wetlands inventory at OLYM. National Wetlands Inventory.
- Need to identify the types, location area, extent and condition of wetlands for park planning.
- Human influences on wetlands are considered low to moderate and are mainly from road runoff along transportation corridors.
- Significance to park management is very high. Need to know location and extent of wetlands in the park. Will help determine if management or maintenance projects need additional funding for wetlands compliance.

Recommendations

- Inventory: Conduct a wetlands inventory in OLYM. Request technical assistance from NPS Water Resources Division to the NPS Water Resources Division, for a wetland inventory. Focus wetland inventory efforts on existing and potentially future developed corridors. Submit a request for using a Geoscientist-in-the-Park (GIP) to help with wetlands mapping.

Tectonics and Gravity Geoindicators

Slope failure (landslides)

Background

Slope failures are caused by mass wasting (rock falls, landslides, debris flows, slumps, soil creep) as opposed to fluvial (water) erosion. Slopes stability is dependent on slope gradient or steepness, water content and soil water pressure, type of underlying geology, and local environmental factors such as ground temperature. Slope failures may take place suddenly and catastrophically, resulting in debris torrents, lahars, rock falls, slides and flows. Or slopes failure may result in a slow downslope movement of material (slides slumps, earthflows, complex landslides and creep). There are innumerable small to medium-size slope failures that cumulatively impose costs to society as great or greater than the large infrequent catastrophic landslides that draw so much attention. Locally landslides may significantly alter terrestrial and aquatic habitats. Landslides are an important geologic process that delivers large woody debris to stream channels. For example, debris torrents involve rapid movement of large volumes of water charged soil, rock and woody debris. They can denude hillslopes, scour stream channels, and deposit large volumes of sediment and wood, and block streams.

Landslide hazard is determined through a risk analysis of the probable recurrence (how often) and potential volume of material, and identifying what resources are at risk in a slope failure. Human activity such as developments, timber harvesting, and road building can change the rate, frequency, spatial distribution and size of the failure.

Points of Discussion

Past and present landslides continue to modify and shape the landscapes in Olympic National Park. Landslides within the park are a natural process unmodified by human activities. Adjacent and outside the park boundaries landslide processes have been significantly modified by human activities, primarily timber harvest and road building. In these areas, human activities have altered the magnitude, frequency and spatial distribution of landslides.

- Slope stability is considered highly significant to the park ecosystem. Landslides are an important mechanism that delivers large trees to stream channels in the park.
- Slope stability is an issue on private lands adjacent to the park boundary. Slope failures are associated with roads and land use in the area that separates the main body of the park and the coastal strip. Sediment delivered to streams has caused the streambed to aggrade and affects anadromous salmonid access to park streams. Increased sedimentation also has caused increased stream temperatures.
- Coastal bluff retreat along Highway 101 may be caused by: drainage issues from the highway; sea level rise(wave action at toe of bluffs); and/or high rainfall events.
- Many roads are causing impacts to streams by initiating slope instability.
- Trails in the park also affected by shallow debris slides.
- In Finley Creek, human activities have caused landslides. Sediment delivered to streams has caused significant streambank erosion and channel aggradation. Sediment impacts to the bridge on Finley Creek is a management issue for the park.
- Vegetation management issue- planting of grass rather than woody vegetation
- Lake Ozette contains a federally threatened specie of Sockeye salmon. Most of the watershed draining into Lake Ozette is outside the park boundaries. The eastside of the lake has been heavily logged. Land use has caused increased delivery of sediment to the lake from landslides, bank erosion and road runoff. Spawning gravels used by salmon at the edge of the lake are being buried with fine sediment. The loss of spawning gravels is exacerbated by the colonization of the fine sediment with canary grass. Numerous sources for fine sediment and includes: roads, hillslope runoff, landslides, etc.

Recommendations

- Inventory: Inventory landslides in the park (debris torrents, debris slides, larger deep seated landslides), determine distribution, frequency and activity levels of features. Using sequential air photos to document landslide history in the park using available photos that bracket pre and post large storms and timber harvesting. Periodically update landslide mapping following large storm events or every 5-years.
- Develop a landslide risk and hazard analysis for landslide prone areas of OLYM. Develop a map of slope stability along developed corridors in the park (roads, visitor centers, developments, facilities and infrastructure)
- Monitor and evaluate groundwater effects on landslide processes for deep seated and shallow landslides.
- Lidar (light detecting and radar) is a new remote sensing tool that can be used for many different types of watershed evaluations (map vegetation structure, faults, channel bed elevations) and is a useful tool for landslide mapping. However, high

mobilization costs for flying lidar. The Puget Sound Lidar Consortium was established as an effort to pool resources between agencies to defray the cost of lidar (USGS, NASA, City of Seattle, counties, etc). University of Washington has developed software to process imagery.

- Contact Puget Sound Lidar Consortium to see if park can cost share on lidar efforts in Puget Sound area.
- Investigate to see if future lidar in OLYM might be funded through the geologic mapping program in the NPS.
- Tom Schindler has lidar of coastal strip the extends inland from the shoreline up to 1100 foot elevation, covers an area along the Juan de Fuca Strait.
- Lidar (ATM) was used to map an 800 foot coastal strip along the Washington coast in fall 2002. Contact John Brock, USGS for more information.
- Research: Try to date large landslide features and tie to known seismic events. Preliminary investigation by Pat Pringle, Division of Geology, Washington Department of Natural Resources.
- Research: Identify mechanisms of failure for coastal bluffs (rainfall events versus wave cut event). Determine probability of wave attack and correlate with bluff erosion.
- Create a database of available aerial photography for OLYM and adjacent areas. Sources of Photography:
 - Dept of Ecology website – retake aerial photography on a five-year interval
 - Washington Coastal Zone Atlas
 - Washington Department of Transportation has images of roads, milepost by milepost, videography, and low-angle oblique photos.
 - Military satellite imagery

Seismicity

Background

Earthquakes constitute one of the greatest natural hazards to human society. Surface effects include uplift or subsidence, surface faulting, landslides and debris flows, liquefaction, ground shaking, and tsunamis ('tidal' waves). Damage to buildings, roads, sewers, gas and water lines, power and telephone systems, and other built structures commonly occurs. Earthquakes can result in marked temporary or permanent changes in the landscape, depending on the magnitude of the earthquake, the location of its epicenter, and local soil and rock conditions. Seismic hazard maps can be constructed to identify areas at varying risk from earthquake damage.

Points of Discussion

Large earthquakes create ground shaking that can trigger landslides, changing flow regimes in rivers and springs, cause liquifaction of unconsolidated sediments. Offshore of OLYM is the Cascadia Subduction Zone (CSZ) which is capable of producing great earthquakes (> magnitude 9). The recurrence interval for the CSZ is 300-800 years and the last great earthquake occurred in 1700.

- Human impacts on seismicity are negligible. However, seismic energy release from large earthquakes may cause considerable damage to park facilities, developments, road networks.
- Management significance is high in preparing and mitigating for seismic hazards for park facilities and developments.

Recommendations

- Future park planning considerations and emergency planning should address seismic hazards. Insure future developments and facilities will consider earthquake and tsunami issues, and are not in areas prone to ground failure, rupture, liquefaction or tsunami inundation zones and built to current seismic standards. Incorporate earthquake issues into OLYM General Management Plan planning considerations.
- The coastal areas of OLYM are at risk from locally generated and distance source tsunami. Identify the tsunami hazard zone for coastal areas and establish evacuation routes. Provide public education on coastal hazards.

Surface Displacement

Background

Most surface displacements have but minor effects on landscapes and ecosystems. However, there are exceptions, such as where drainage channels are suddenly displaced by faults, or where seismically induced uplift raises intertidal ecosystems above sea level. Moreover, extraction of fluids can induce land subsidence and cause flooding, especially of coastal parklands near sea level. Subsidence damages buildings, foundations and other built structures.

Points of Discussion

- As a result of active tectonic processes, the Olympic Mountains are still rising at about 1.8 mm/year. Uplift rates exceed erosion rates.
- In OLYM, there is no human influence on surface displacement.
- During large Cascadia earthquakes, potential downdrops and uplift along the coast will impact coastal processes and organisms in intertidal zones, park visitors, and park facilities, developments and infrastructure. When large earthquakes occur, management significance for surface displacement will be high.

Recommendations

- Monitor: Existing coastal lidar surveys will provide a baseline on which to document uplift and down drop of coastal areas following the next large Cascadia earthquake. Acquire lidar data of the coastal areas following the next large earthquake.

Soil Geoindicators

Soil Quality

Background

As one of Earth's most vital ecosystems, soil is essential for the continued existence of life on the planet and has a major influence on terrestrial ecosystems. Soils continuously recycle plant and animal remains, and they are major support systems for human life, determining the agricultural production capacity of the land. Soils buffer and filter pollutants, they store moisture and nutrients, and they are important sources and sinks for CO₂, methane and nitrous oxides. Soils are a key system for the hydrological cycle and also provide an archive of past climatic conditions and human influences.

Points of Discussion

- No soil mapping for the park. Need to develop a basic soil map of the park.
- Human influence on soil quality is unknown at this time.

Recommendations

- Inventory- Pursue project with the Natural Resource Conservation Service to map soils in OLYM, NOCA and MORA. Work with Pete Biggam (soil scientist, Geologic Resources Division) and Jon Riedel (geologist, NOCA) to coordinate soil mapping with NRCS in the three parks.
- Research- Determine concentrations of persistent organic pollutants (POP, pesticides, herbicides and heavy metals) in soils. POP's enter the atmosphere as volatile contaminants and are transported across the landscape by wind currents and eventually deposited in the soil by rain.

Soil and Sediment Erosion

Background

Soil erosion is an important social and economic problem and an essential factor in assessing ecosystem health and function. Estimates of erosion are essential to issues of land and water management, including sediment transport and storage in lowlands, reservoirs, estuaries, and irrigation and hydropower systems.

Points of Discussion

- Logging is active on lands adjacent to the park boundary. Timber harvest and road building activities can cause increased hillslope erosion and delivery of sediment to stream channels. If sediment delivered to the channel exceeds the stream capacity, it will be stored in the channel. Outside the park boundary, stream channels are impacted by excess sediment from land use and impacting the access of salmonids to stream reaches located in the park.
- Human influence on soil and sediment erosion is high from logging and road building activities on lands adjacent to the park.
- Some erosion problems associated with social trails in the park, and along some coastal headlands; rope ladders on coastal trails cause some erosion from park visitors.
- Human influence on soil erosion in the alpine and sub-alpine environment is minimal.

- High turbidity in streams occurs during the winter flows. Glaciers are one of the sources of fine sediment.
- Dams on the Elwah River will be removed in the future. The park has significant concerns about the impact of sediment release by the dam on downstream aquatic resources. Interdisciplinary teams of scientists are determining the best course of action to deal with how the dams are removed to minimize resource damage.

Recommendations

- **Monitor:** Develop turbidity monitoring at gaging stations. Share park data with regulatory agencies that address fish and timber issues. REDW is developing protocols for turbidity monitoring and currently has an EPA grant to compare turbidity from disturbed from relatively undisturbed watersheds.
- **Research:** Evaluate impacts of landuse activities on stream channel habitat. Compare stream channel habitat (pool/riffle habitat, sediment size distribution) impacted by land use adjacent to OLYM with park streams that are relatively undisturbed by human activities. Develop partnerships with local tribes, federal and state agencies, and private landowners to cooperatively monitor stream channels, standardize protocols between groups, share resources and data. (see also recommendations section of the Stream channel morphology geoindicator on establishing a stream channel monitoring program)

Other Geoindicators

Sediment Sequence and Composition

Background

The chemical, physical and biological character of aquatic sediments can provide a finely resolvable record of environmental change, in which natural events may be distinguishable from human inputs. Lakes, wetlands, streams and floodplains, estuaries, shallow coastal seas and other bodies of marine or fresh water commonly accumulate deposits derived from within the drainage basin, though fine particles can also be blown in by winds from distant sources (natural, urban and industrial). Of particular value in determining long-term data on water chemistry are the remains of aquatic organisms (e.g. diatoms, and other algae and invertebrates) which can be correlated with various environmental parameters. In addition, fossil pollen, spores, and seeds reflect past terrestrial and aquatic vegetation. These aquatic deposits may preserve a record of past or on-going environmental processes and components, both natural and human-induced, including soil erosion, air-transported particulates, solute transport, and landsliding.

Points of Discussion

- This geoindicator provides decadal scale information.
- Sediment sequence data could help extend records to prehistoric times, provide an indication of the degree and nature of impact of past events in the system, and a baseline for comparison with modern change.
- This geoindicator is considered to be of moderate management significance.

- Help understand rate and pattern of processes (e.g., composition of sediment in coastal bluffs will help to determine the rate of shoreline retreat.).

Recommendations

Research: Study sediment sequence data from sediment fan of lakes cores to determine lake level and sedimentation history (Lake Ozette). See also recommendations section of the Lake level geoinicator for a research on lake level history for Lake Ozette.

- Inventory: Utilize remote sensing techniques for seafloor mapping (multi-beam imagery, side scan radar, seismic reflection). Determine sediment substrates and habitat types of the nearshore/offshore areas of the park. Use seismic reflection data offshore to determine the thickness of sediment sequence for a sediment budget.
- Evaluate if logging activities in the watershed led to sediment deposition offshore of Rialto Beach. Determine if sediment buried and killed kelp beds offshore or prevents the annual recruitment to a more mobile, sandy substrate.
- Study lake sediment cores to determine fire history, study organic pollutants, sedimentation rates, palontology and paleo-climate information. This project is described in the Lake level geoinicator recommendation for research on historic lake level fluctuations.

Additional Geologic Issues

Avalanches

Background

Steep slopes and massive, wet winter snowfall combine to make snow avalanches a significant geological and ecological process. Snow avalanches influence habitat by controlling vegetation patterns, delivering sediment directly to lakes and streams, and altering habitat and biological communities. Avalanches are a natural process where gravity rapidly and catastrophically moves snow from steep slopes to valley bottoms. Global climate change influences avalanche processes through variations in magnitude of winter snowfall amount and air temperature.

Points of Discussion

- Skiers don't trigger avalanches often and the park doesn't trigger avalanches as a management tool. Therefore the management significance is low to moderate.
- Paul Crawford routinely monitors avalanches on Hurricane Road. Northwest Weather and Avalanche Center forecast avalanches and developed a snow avalanche risk map for Hurricane Road.
- Avalanche issues are a low to moderate management significance.

Recommendations

- Inventory- Use GIS topographic information and snowfall data to predict locations of avalanches. Also use aerial photographs to map avalanche features based on vegetation communities (alder dominated) and use topographic maps to identify locations.

- Monitor- Activity of snow avalanches could be monitored through aerial photo analysis of tree invasion into avalanche chutes.
- Research- Evaluate if the magnitude and frequency of snow avalanches has changed as a result of climate change from the little ice age to modern climates (i.e. Are modern avalanches smaller and less frequent).

Geothermal

Points of Discussion

Geothermal springs have a limited occurrence in the park. Hot springs are located at Olympic Hot Springs, Sol Duc Hot Springs and a mineral spring at South Fork Dosewallips River (not recently found).

- Hot spring areas were originally seepage with a unique flora. The natural setting has been completely altered.
- Human influence is high on this geoinicator.
- Hot springs are a moderate management concern.
- Sol Duc Hot Springs Resort is a concession within the park. It is a popular visitor destination and management concerns at the site are moderately political. The hot spring area has been completely altered from original natural setting. Prior to human alterations, geothermal springs were seepages with unique plant assemblages. Development of geothermal springs has concentrated warm water flow into hot pools. Low flows have caused high E. Coli counts. To address E. Coli, concession adds chlorine to pools every night and management of hot springs causing point source discharge of chlorine into the stream.
- Olympic Hot Springs are an undeveloped spring area. Visitors locally alter the hot spring area.
- USGS report by Norm Dion identified the geothermal hot springs as an artesian source.

Recommendations

- Monitor-water quality above and below the hot springs to determine if point source of chlorine is altering water quality.
- Monitor- long-term water quality and chemistry, water temperature and flow rate of springs.

Intertidal Zones

Points of Discussion

Intertidal zones include both tidepools and tidelands. The intertidal zone is a highly significant resource to park visitors and like the rainforest, is considered a vital component of OLYM. Tidepools are considered a significant park visitor resource

- Human influences on intertidal zones include harvesting and physical trampling of biota. Intertidal zones provide a geologic interface for biota.

- Rocky intertidal zones are distributed throughout the coastal areas of the park and can be found at north of Rialto, Point of the Arches and north of Ruby Beach. Southern beach trails from Beach 4 south are more sandy.
- Park boundary extends out to offshore islands. Offshore islands are in the jurisdiction of the U.S. Fish and Wildlife Service.
- Dr. Carl Schoch has developed a geomorphic characterization of intertidal areas.
- Changes in sediment regime can cause a sediment accumulation in intertidal areas.

Recommendations

- Research: Evaluate the effects of trampling by visitors on the intertidal resources. Establish intertidal transects. Inventory intertidal organisms and fish. Good graduate thesis.
- Research: Evaluate response of coastal areas to sediment pulses from coastal watersheds. Sediment delivery and transport regimes may change on coastal rivers from increased landsliding and increase sediment delivery to coastal cells.